

ASC-TR-2000-5012



**A HUMAN FACTORS STUDY
OF A HELMET MOUNTED DISPLAY
FOR THE PILOTS OF THE B-1B**

**MAJOR SCOTT PROVOST
MR. WILLIAM G. KALMAN
DR. BEVERLY A. GABLE**

**CREW STATION EVALUATION FACILITY
ASC/ENFC
2530 LOOP ROAD WEST
WRIGHT-PATTERSON AFB, OH 45433-7101**

SEPTEMBER 2000

FINAL REPORT FOR 01 MARCH – 30 SEPTEMBER 2000

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

**ENGINEERING DIRECTORATE
AERONAUTICAL SYSTEMS CENTER
AIR FORCE MATERIEL COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OH 45433-7101**

REPORT DOCUMENTATION PAGE

1. REPORT DATE (DD-MM-YYYY) 01-09-2000	2. REPORT TYPE Final Report	3. DATES COVERED (FROM - TO) 01-03-2000 to 30-09-2000
4. TITLE AND SUBTITLE A Human Factors Study of a Helmet Mounted Display for the Pilots of the B-1B Unclassified	5a. CONTRACT NUMBER	
	5b. GRANT NUMBER	
	5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Provost, Scott ; Kalman, William G. ; Gable, Beverly A. ;	5d. PROJECT NUMBER	
	5e. TASK NUMBER	
	5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME AND ADDRESS Crew Station Evaluation Facility ASC/ENFC 2530 Loop Road West Wright-Patterson AFB , OH 45433-7101	8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME AND ADDRESS Engineering Directorate Aeronautical Systems Center Air Force Materiel Command Wright-Patterson AFB , OH 45433-7101	10. SPONSOR/MONITOR'S ACRONYM(S)	
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT A PUBLIC RELEASE Engineering Directorate Aeronautical Systems Center Air Force Materiel Command Wright-Patterson AFB , OH 45433-7101		

13. SUPPLEMENTARY NOTES**14. ABSTRACT**

The objective of this study was to conduct a human factors evaluation of a conceptual Helmet Mounted Display (HMD) compared to Head Down displays (HDDs) in the JDAM/LAR environment, ten B-1B pilots flew 1203 minute missions, with 4 display conditions, and 3 route conditions. The displays were a HMD, a 4'x4" LCD, a 8'x6" LCD and the B-1B Block displays (in order). Recommendations were made for improving the HMD.

15. SUBJECT TERMS

B-1B; Human Factors; Helmet Mounted Display (HMD); Liquid Crystal Display (LCD); Launch Acceptability Region (LAR); Joint Direct Attack Munition (JDAM)

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Public Release	18. NUMBER OF PAGES 56	19a. NAME OF RESPONSIBLE PERSON Fenster, Lynn lfenster@dtic.mil
a. REPORT Unclassified	b. ABSTRACT Unclassified	c. THIS PAGE Unclassified			19b. TELEPHONE NUMBER International Area Code Area Code Telephone Number 703 767-9007 DSN 427-9007

NOTICE

USING GOVERNMENT DRAWINGS, SPECIFICATIONS, OR OTHER DATA INCLUDED IN THIS DOCUMENT FOR ANY PURPOSE OTHER THAN GOVERNMENT PROCUREMENT DOES NOT IN ANY WAY OBLIGATE THE US GOVERNMENT. THE FACT THAT THE GOVERNMENT FORMULATED OR SUPPLIED THE DRAWINGS, SPECIFICATIONS, OR OTHER DATA DOES NOT LICENSE THE HOLDER OR ANY OTHER PERSON OR CORPORATION; OR CONVEY ANY RIGHTS OR PERMISSION TO MANUFACTURE, USE, OR SELL ANY PATENTED INVENTION THAT MAY RELATE TO THEM.

THIS REPORT IS RELEASABLE TO THE NATIONAL TECHNICAL INFORMATION SERVICE (NTIS). AT NTIS, IT WILL BE AVAILABLE TO THE GENERAL PUBLIC, INCLUDING FOREIGN NATIONS.

THIS TECHNICAL REPORT HAS BEEN REVIEWED AND IS APPROVED FOR PUBLICATION.

17 OCT 2000

03 OCT 2000

William D Kalman

WILLIAM G. KALMAN
Program Manager
Crew Station Evaluation Facility

R. Kevin Burns

R. KEVIN BURNS, Chief
Crew Systems Branch
Flight Systems Engineering Division

03 OCT 2000

Beverly A. Gable

BEVERLY A. GABLE, Dr.
Human Factors Engineer
B-1 Systems Program Office

Frank M. Stauble for

DONALD R. CHISLAGHI
Chief, B-1 Engineering
B-1 System Program Office

03 OCT 2000

25 OCT 2000

03 OCT 2000

Frank M. Stauble

FRANK M. STAUBLE
Chief, Systems Support Branch
B-1 Systems Program Office

Alan F. Bailey

ALAN F. BAILEY, Chief
Flight Systems Engineering Division
Engineering Directorate

Do not return copies of this report unless contractual obligations or notice on a specific document requires its return.

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
<small>Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Service, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.</small>				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE SEPTEMBER 2000	3. REPORT TYPE AND DATES COVERED Final Report for 01 MARCH - 30 SEPTEMBER 2000	
4. TITLE AND SUBTITLE A HUMAN FACTORS STUDY OF A HELMET MOUNTED DISPLAY FOR THE PILOTS OF THE B-1B			5. FUNDING NUMBERS	
6. AUTHOR(S) MAJOR SCOTT PROVOST, MR. WILLIAM G. KALMAN, and DR. BEVERLY A. GABLE,				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) CREW STATION EVALUATION FACILITY ASC/ENFC 2530 LOOP ROAD WEST WRIGHT-PATTERSON AFB, OH 45433-7101			8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) ENGINEERING DIRECTORATE AERONAUTICAL SYSTEMS CENTER AIR FORCE MATERIEL COMMAND WRIGHT-PATTERSON AIR FORCE BASE, OH 45433-7101 POC: MR. WILLIAM G. KALMAN, ASC/ENFC, (937) 255-4258			10. SPONSORING/MONITORING AGENCY REPORT NUMBER ASC-TR-2000-5012	
11. SUPPLEMENTARY NOTES NONE				
12a. DISTRIBUTION AVAILABILITY STATEMENT APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) The objective of this study was to conduct a human factors evaluation of a conceptual Helmet Mounted Display (HMD) compared to Head Down Displays (HDDs) in the JDAM/LAR environment. ten B-1B pilots flew 120 3 minute missions, with 4 display conditions, and 3 route condition. The displays were a HMD, a 4" X 4" LCD, a 8" X 6" LCD, and the B-1B Block displays (in order). Recommendations were made for improving the HMD.				
14. SUBJECT TERMS B-1B, HUMAN FACTORS, HELMET MOUNTED DISPLAY (HMD), LIQUID CRYSTAL DISPLAY (LCD), LAUNCH ACCEPTABILITY REGION (LAR), JOINT DIRECT ATTACK MUNITION (JDAM)			15. NUMBER OF PAGES 56	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT SAR	

TABLE OF CONTENTS

<u>Section</u>	<u>PAGE</u>
LIST OF ANACRONYMS.....	v
1.0 INTRODUCTION	1
2.0 STUDY OBJECTIVE.....	2
3.0 METHOD.....	3
4.0 RESULTS.....	12
5.0 RECOMMENDATIONS.....	12
APPENDIX A: DISPLAY TECHNICAL DESCRIPTIONS	15
APPENDIX B: QUESTIONNAIRES	16
BIBLIOGRAPHY	51

LIST OF FIGURES

<u>Figure</u>	<u>PAGE</u>
FIGURE 1. MAIN INSTRUMENT PANEL LAYOUT.....	4
FIGURE 2. 4" X 4" LCD.....	4
FIGURE 3. 8" X 6" LCD.....	5
FIGURE 4. ANNOTATED LCD SYMBOLOGY.....	6
FIGURE 5. HMD SYMBOLOGY.....	7
FIGURE 6. ANNOTATED HMD SYMBOLOGY.....	8
FIGURE 7. HMD HARDWARE.....	9
FIGURE 8. ALWAYS PRESENT AIRCRAFT DATA.....	10

LIST OF ANACRONYMS

A/C	Aircraft
ALT MSL	Altitude Mean Sea Level
CSEF	Crew Station Evaluation Facility
DMPI	Desired Mean Point of Impact
ERS	Engineering Research Simulator
FOV	Field of View
HDD	Head Down Display
HMD	Helmet Mounted Display
JDAM	Joint Direct Attack Munition
JHMCS	Joint Helmet Mounted Cueing System
LAR	Launch Acceptability Region
LCD	Liquid Crystal Display
MRAD	Milliradian
NM	Nautical Miles
SAM	Surface to Air Missile
TTG	Time to Go
UTTR	Utah Test and Training Range
VSD	Vertical Situation Display

1.0 INTRODUCTION

1.1 Over the last several years, the B-1B System Program Office Engineering Department (ASC/YDE) in conjunction with the Crew Station Evaluation Facility (CSEF) of the Engineering Directorate of Aeronautical Systems Center (ASC/ENFC) has conducted a series of applied human factors engineering studies. The CSEF has used the B-1B Engineering Research Simulator (ERS) as a major tool in these human-in-the-loop simulation studies.

1.2 Some examples of past efforts include the Defensive System Upgrade Program studies, Conventional Mission Upgrade Program studies, Block Upgrade studies, Crew Station Working Group support, a Link 16 Study, B-1B Blocks D, E, and F Baseline Study, and an Alternative Launch Acceptability Region Study. Government engineers have worked closely with the contractors, Boeing (B-1B), and L-3 Communications, Link Simulation and Training to support these efforts. The CSEF has helped fold these results back into the B-1B system to make it a safer and more effective system.

1.3 New smart weapons and advanced avionics systems have spurred the need for B-1B upgrades. The current B-1B Block D upgrade provides the B-1B the capability to carry up to 24 Joint Direct Attack Munitions (JDAMs). The JDAM tail kit turns a 2000-pound dumb bomb (e.g., Mark 84) into a global positioning system and inertial navigation system guided near precision weapon. This increase in weapon capabilities also increases mission complexity. Before Block D, the B-1B would drop multiple bombs on a single target area. Now the B-1B has the capability to direct individual weapons to individual target points. Since a JDAM is a guided weapon, the weapon launch point has expanded into a region. The launch acceptability region (LAR) is the area from which the JDAM must be launched by the B-1B in order to achieve the desired mean point of impact (DMPI). Mission complexity arises when multiple DMPIs are compressed in time and bomb runs are conducted in a threat environment. Further complexity is introduced due to the possibility of system malfunctions such as hung stores. This increased weapon and mission complexity may require upgraded controls and display technology so that the crew is not task saturated and retains situational awareness.

2.0 STUDY OBJECTIVE

2.1 The objective of this study was to conduct a human factors evaluation of a conceptual Helmet Mounted Display (HMD) compared to Head Down Displays (HDDs) in the JDAM/LAR environment.

3.0 METHOD

3.1 The CSEF's B-1B ERS was used. All study participants flew from the pilot's seat. A 4" X 4" color liquid crystal display (LCD) and an 8" X 6" color LCD, or HDDs, as well as a HMD were operational on the pilot's side. See Appendix A for technical descriptions of the LCDs and HMD. See FIGURE 1 for the main instrument panel layout. Note that FIGURE 1 represents the Block D displays except for the LCDs.

3.1.1 HMD Head Tracker

The HMD had a head tracker of the magnetic field type. The tracker determined the helmet, ground, and aircraft spatial relationships in pitch, roll, and yaw and moved the symbology within the HMD field of view accordingly. This process operated in real time. The tracker and HMD and the HMD combiner glass/eye relationships were calibrated before the HMD missions were flown. The ERS's magnetic field was not mapped. Magnetic field mapping may aid tracker accuracy.

3.1.2 Symbology

See FIGURES 2 and 3 for the LCD symbology. The 4" X 4" and 8" X 6" LCDs had the same symbology and scale. See FIGURE 4 for an annotated breakdown of the LCD symbol set. The HMD symbology gave JDAM LAR steering cues (see Provost, et. al., 2000). The core concept of the HMD symbology was that the JDAM footprint was flown by the pilot in such a way so as to lay or fly the LAR ground footprint overtop the DMPIs. The symbology design (see FIGURE 5) was coordinated with ASC/ENFC and is similar in concept to the F-22 JDAM/LAR head down display symbology. See FIGURE 6 for the annotated HMD symbology. The same LAR software algorithm drove the HDDs and HMD. See figure 7 for the HMD hardware. Note that FIGURE 7 does not show the ERS mounted magnetic field transmitter and the corresponding helmet mounted receiver. Except for the LCDs and HMD, the B-1B ERS was in the Blocks D configuration. Since the 8" X 6" LCD replaced other aircraft information, that missing aircraft information was always provided by the 8" X 6" LCD (see FIGURE 8).



FIGURE 1. MAIN INSTRUMENT PANEL



FIGURE 2. 4" X 4" LCD



FIGURE 3. 8" X 6" LCD

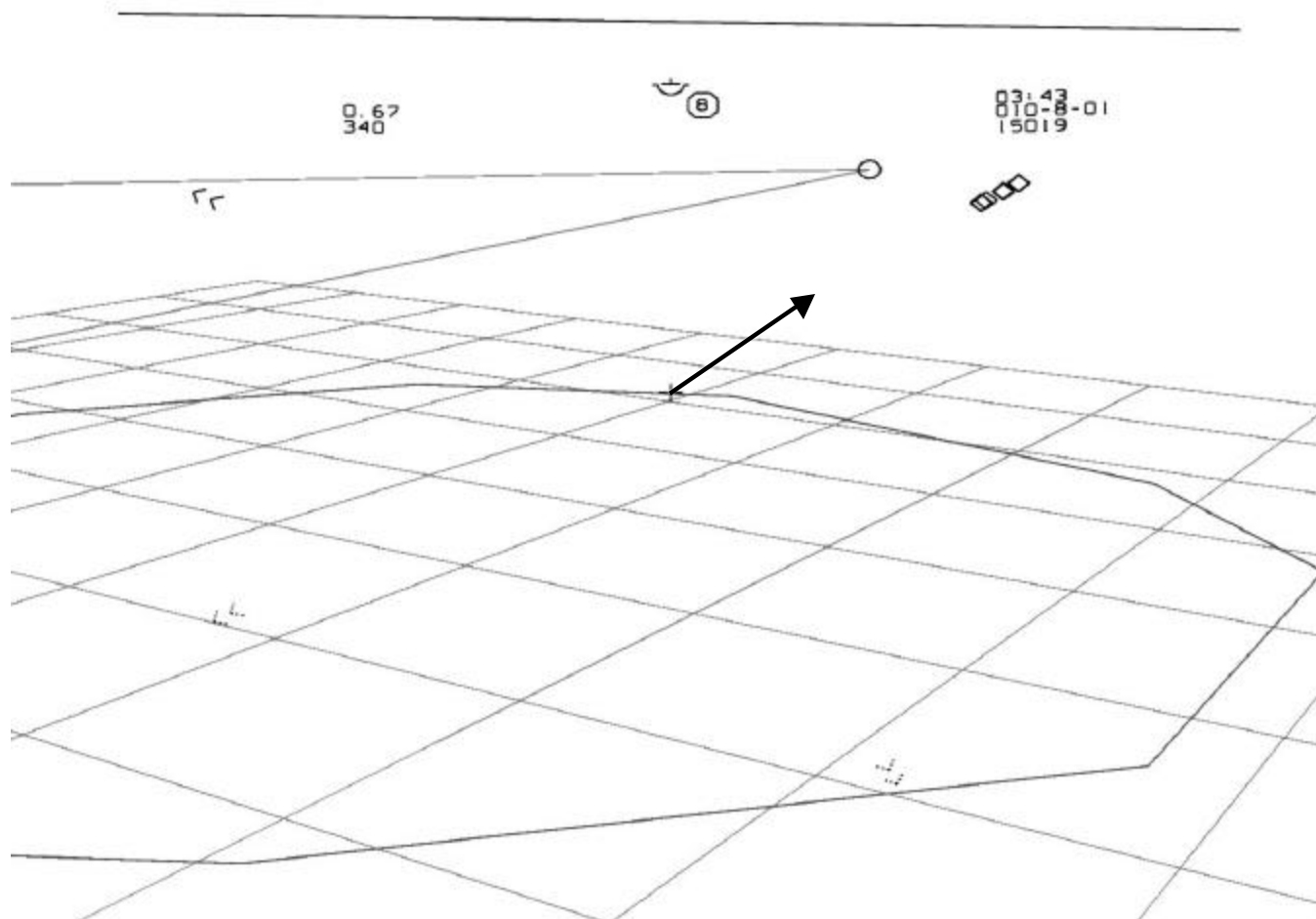


FIGURE 5. HMD SYMBOLOGY

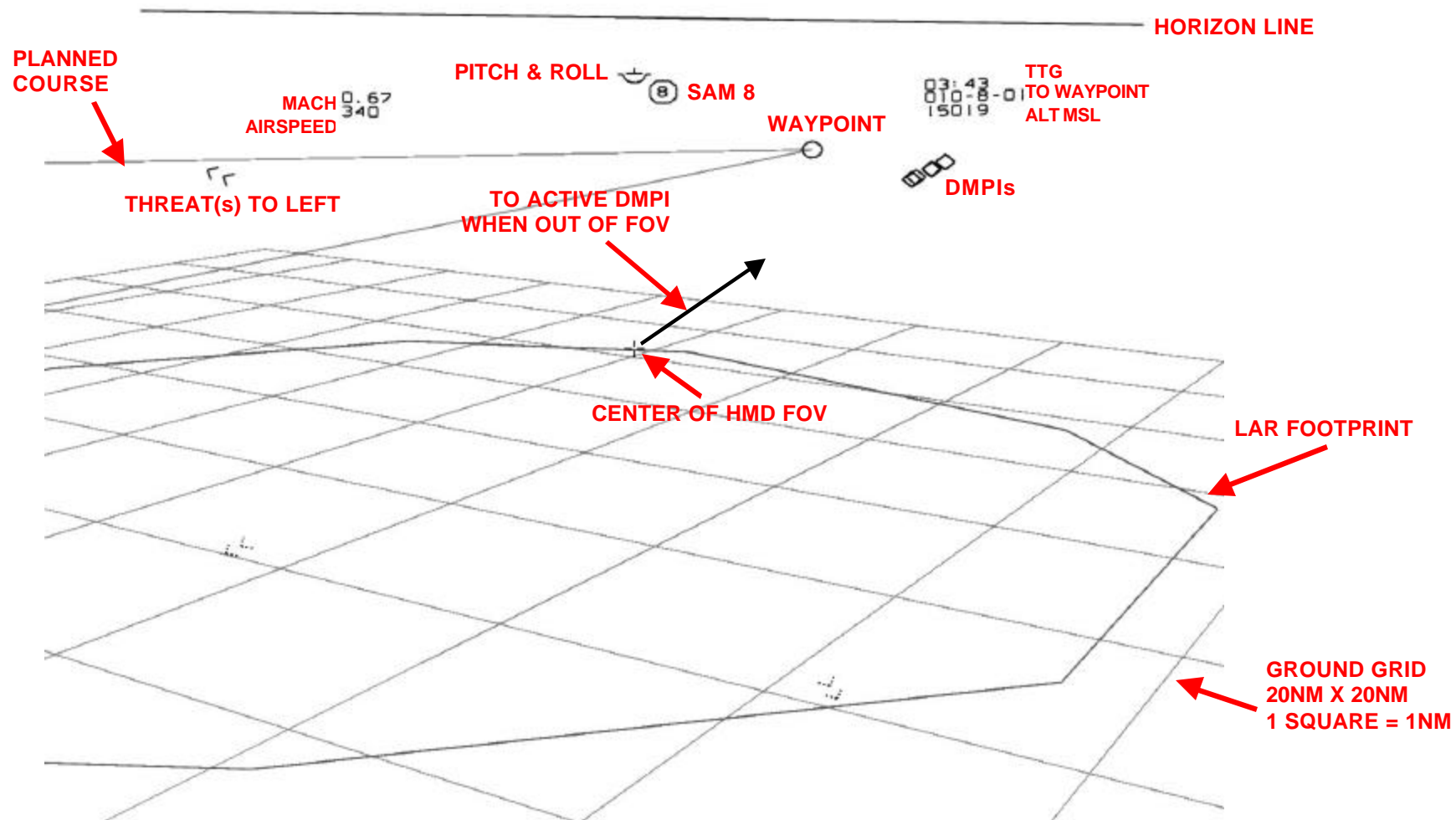


FIGURE 6. ANNOTATED HMD SYMBOLOGY



FIGURE 7. HMD HARDWARE

	PT	SEQ
	I	010-9
	TTG	
	00:02:41	
	FLAPS	
	UP	
	SLATS	
	RET	
	RUDDER	
	R00°	
	SPD BRKS	
	00°	
	SPLR	TRIM
	R00°	L00°
	STAB	
	R+00°L+00°	
	CMD WNG	
	26°	
	WING SWP	
	26°	

FIGURE 8. ALWAYS PRESENT AIRCRAFT DATA

3.2 Subjects and Training

Ten B-1B pilots were subjects. Pilots received classroom training prior to data missions. Practice missions were flown prior to data missions.

3.3 Missions

Missions were based on a standard Utah Test and Training Range (UTTR) scenario (see Kalman, et al., 2000). Each data mission lasted approximately 3 minutes. Between one to four threats were present. The threat types were SA 3, SA 6, SA 7, and SA 8. Threat number, type(s), and location(s) within a mission were randomly selected.

3.4 Experimental Design and Independent Variables

The pilots flew four different configurations or display types:

- a. Block D only
- b. 4" X 4" LCD
- c. 8" X 6" LCD
- d. HMD

Each configuration had three different mission scenarios:

- a. On planned course and heading towards targets
- b. Slightly off of planned course and heading back to planned course
- c. Significantly off of planned course and also heading away from planned course

Thus, this was a 4 X 3 repeated measures within subjects experimental design. Each pilot flew a total of 12 data missions. A pilot flew the three missions within a configuration condition or display type in a random order. The order in which one of the four configurations was flown was also randomly assigned. Pilots flew with only one display type at a time. Pilots did not have the ability to select or change displays (e.g., map scale) during a mission.

3.5 Dependent Measures

Questionnaire information was collected. Questionnaire information for a display configuration was collected immediately after the three mission scenarios were flown for that display condition. The questionnaire followed the general principles contained in the Army's Questionnaire Construction Manual (1989). All missions were video taped.

4.0 RESULTS

- 4.1 All of the questionnaire results, including pilot comments, are in Appendix B. A few of the highlights from the questionnaire are below. The following rating scale was used:

7 Totally Acceptable
6 Very Acceptable
5 Somewhat Acceptable
4 Borderline
3 Somewhat Unacceptable
2 Very Unacceptable
1 Totally Unacceptable

- 4.2 Noteworthy question—

(Note: The following question was answered after all 12 missions had been flown.)

“1. All things considered, please **RANK ORDER** the following from an operational viewpoint (1 = best, 4 = worst):

1.4 - 4” X 4” HDD
1.8 - 8” X 6” HDD
2.8 - HMD
4.0 - Block D Displays”

- 4.3 Noteworthy question

“11. All things considered, rate the **OVERALL** Operational Utility of a **HMD** in the B-1B. Use the following scale:

RATING: average = **5.4 Somewhat Acceptable**

- 4.4 Noteworthy question

“22. All things considered, rate the **OVERALL** Operational Utility of a **4” X 4” HDD** in the B-1B. Use the following scale:

RATING: average = **6.7 Very Acceptable**

- 4.5 Noteworthy question

“32. All things considered, rate the **OVERALL** Operational Utility of an **8” X 6” HDD** in the B-1B. Use the following scale:

RATING: average = **6.4 Very Acceptable**

4.6 Noteworthy question

“42. All things considered, rate the OVERALL Operational Utility of **Block D Displays** in the B-1B. Use the following scale:

RATING: average = **3.2 Somewhat Unacceptable**

4.7 Other results

- a. 120 ERS missions flown
- b. Pilots from:
 - 2 - 34th Bomb Squadron
 - 3 - Detachment 2, 53rd Test & Evaluation Group
 - 1 - 184th Bomb Squadron
 - 3 - 9th Bomb Squadron
 - 1 - ASC/YDE
- c. Average B-1B hours = 1185.1
- d. B-1B hours range = 96 to 2955
- e. Other aircraft average hours = 892.2
- f. Other aircraft hours range = 45 to 2430

5.0 RECOMMENDATIONS

- 5.1 Recommend that a HMD for the B-1B not be pursued further as mechanized herein. HDDs should be pursued. A god's eye view of the world is preferable to a panoramic overlay on the world. There is a fundamental mismatch in trying to adapt a HMD, whose forte is the vertical situation, to rectify B-1B deficiencies in horizontal situational awareness. This mismatch may have safety implications such as disorientation and incorrect information interpretation.
- 5.2 Recommend that additional displays be made available in the front cockpit of the B-1B. The Block D displays are unacceptable for JDAM missions where there is a possibility of the aircraft going off of the black line or planned route. This is directly related to unacceptable LAR and threat situational awareness up front.
- 5.3 Recommend that the displays should be integrated into the B-1B system, regardless of display type. For example, if integrated, the displays can provide critical LAR and threat information. If the displays are not integrated, they can only supply very limited information.
- 5.4 Recommend that if a HMD is pursued further, additional targeting (e.g., time-to-weapon release), perhaps different LAR formatting (e.g., LAR-in-the-sky), better vertical situation information (e.g., pitch ladder, velocity vector), and range to threat information should be explored. Also the HMD restricts the pilot's ability to choose information input. This may restrict proper use of control instruments (e.g., VSD). This should also be explored.
- 5.5 Recommend that if HDDs are used, then they be located in the best possible cross-check location. The 4" X 4" HDD was preferred over the 8" X 6" HDD because of its better location in the main instrument panel (see FIGURE 1). This made for easier instrument cross-checks and transitions from head down to head up.

APPENDIX A: DISPLAY TECHNICAL DESCRIPTIONS

A.1 Rockwell Collins 4" x 4" (FDS-255):

Color Active Matrix LCD
4.22" x 4.22" Viewable Area
Box = 5.08"H x 5.08"W x 8.75" D
RS-170 video (525 lines)
64 Shades of Grey, 256 Symbol Colors
NVIS Compatible
Viewing Angle +/- 65°H, +40°/-20°V

A.2 Computer Dynamics 8" x 6" (SH23):

Color Active Matrix LCD
Glass made by Lucky Gold Star
8.3"W x 6.2"H Viewable Area
Box = 8.6"H x 12.6"W x 3.5"D
For this study RS-170 video (525 lines)
64 Shades of Grey
256 Colors
Viewing Angle +/-40°H, +10°/-30°V

A.3 Kaiser SIM EYE™ 40 HMD (as used in this study)

Monocular Field of View = 40°
Binocular Field of View = 40°V x 60°H (divergent overlap)
Resolution = 2 arc minutes @ 1280 X 1024
Display Luminance = 6 foot lamberts
Head Supported Weight = 4.5 pounds
Input Video Format = 1280 x 1024 @ 2:1 non-interlaced, 60 hertz
Color = monochromatic - green

APPENDIX B: QUESTIONNAIRES

B-1B Helmet Mounted Display (HMD) and Heads Down Display (HDD) Concepts Questionnaire

This B-1B Engineering Research Simulator (ERS) evaluation of the HMD and HDD does not imply or promise any commitment by ASC/YD to the actual implementation of such a system or systems. This is an evaluation of **CONCEPTS** only and is not intended to reflect what a mature hardware or software design might be like if one of these systems is implemented.

Your Name, Rank, and Phone Number will be kept private and will not appear in any reports in this study.

Pilot or Copilot Experience:

Total B-1B Flight Hours: **Average: 1185¹ Minimum: 96 Maximum: 2955**

Other aircraft average hours = **892.2**

Other aircraft hours range = **45 to 2430**

Instructions: Please insure that your equipment is donned appropriately and the ejection seat harness is properly attached. Position the seat in your normal combat position. Assume your normal relaxed posture. Note that the term “symbolology” as used below also included alphanumerics. Note that the term “black line” refers to the planned route.

Please answer the following Question after flying all missions:

1. All things considered, please **RANK ORDER** the following from an operational viewpoint (1 = best, 4 = worst):

- 2.8** HMD
- 1.4** 4” X 4” HDD
- 1.8** 8” X 6” HDD
- 4.0** Block D Displays

¹ A bold face number generally indicates the score for a question, usually an average.

Comments²:

- Any of these would be a significant SA improvement. Very needed in the dynamic Block D / JDAM environment. The HMD could be good but symbology for me is not as intuitive as the God's eye, straight down, course lines + LARs. Easy to fly through all LARs with either 4x4 or 6x8. 4x4 HDD was right in field of view as far as normal inst scan goes. Very easy to incorporate into scan and solves left vs. right readability issues – not an issue if we both have one. Don't need to add airspeed + alt info as I suggested on 6x8 because the 6x8 was further away from your normal instrument scan. Bottom line: operationally, I'd take the 4x4 right now, and any of the others w/a little more refinement. Current Block D displays are unsat: no LAR depiction, no course depiction, no threat depiction, etc, etc, etc.
- The current Block D display is of no use to the pilot. The OSO is the only one with SA. The HMD is too cumbersome and does not provide the needed info (i.e. Threat ranges & nav info). Fatigue is also an issue with the HMD. There is no way one could fly a 5+ hour sortie with that thing. Also, I want/need an NVG capability, which is not currently possible with the HMD. The 8x6 is good but the crosscheck is too far apart. The 4x4 is the best option in my opinion. All of the necessary info is right in front of you in a great and easy location.
- 8x6 was easiest to use, 4x4 was slightly harder to see, HMD – symbology, head movement were distracting. HMD – symbology / info needs to be better. HMD isn't much good if your head is "down" trying to drag weapon footprint through DMPI release point. Need to develop symbology / graphics that are at flight level & allow head to be more level. (Either or God's eye view options.) Put threat rings / bubbles up on HMD as well (corrected for altitude). Again the idea would be to fly jet through all LAR "baskets" and avoid all threat "bubbles".
- If I could only have one of the four I would like the 8x6 HDD. I think it provides the most information. The HMD combined with a HDD would provide the B-1 with both an increase in pilot SA and a much-needed heads up capability. I liked the bigger 8x6 displays better.
- The HMD and HDDs were all great. They all provide pilots SA on target/threats. I liked the location and info on 4x4 best mostly because it was easiest to fly the jet with it. There's a slightly more time consuming crosscheck with the 8x6 from the copilot seat. There's probably more capability with the 8x6 for more info i.e. moving map etc. The HMD would require more brain bytes to fly the jet and process target info, but after getting used to prioritizing the info you see its great for providing a real-time picture for changing footprint info and threat location. An easy way to turn the display off would be nice.
- I found the HMD, 4x4, and 6x8 all to be acceptable ways of solving the LAR situational awareness problem in the current Block D displays. Rank ordering the 3 was difficult because the type LAR display in the HMD was different than the HDDs. I personally prefer the God's eye view provided by the HDDs, but would be very pleased if that kind of presentation was programmed into a helmet display.
- The increased SA of the 4x4 display is amazing. It should be in the jets now. I didn't find any advantage in the larger 8x6. The HMD has a long way to go before I believe

² All comments are quoted from the questionnaire.

it will be useful and comfortable. A smaller device and more representation of symbols, DMPIs and threats need to be developed. Once these items have been worked out, I believe it would be a valuable piece of equipment to aid the pilots in releasing their weapons, and at the same time, keeping their SA in where the threats are.

- Block D by far the worst. The ease and familiarity of HDDs made them a favorite over HMD. Excellent SA provided by all current displays.
- Block D as currently exists is not acceptable. Any of the HDD or HMD would be acceptable. HDD – God’s eye view is more intuitive. HMD would require additional training – not as intuitive as flat panel display. HMD format not as easily integrated – if flat panel display was displayed in HMD it would be easier to understand process.

SECTION 1 - HMD

2. Rate the acceptability of the **Physical Fit** of the HMD (e.g., fit, chin strap, weight, center of gravity, etc.). Use the following scale:

Ratings:	
7 Totally Acceptable	
6 Very Acceptable	4
5 Somewhat Acceptable	3
4 Borderline	2
3 Somewhat Unacceptable	
2 Very Unacceptable	1
1 Totally Unacceptable	

RATING: Average: 4.9

Comments:

- Would be fine with your own custom fit helmet.
- For a short sortie this would probably be acceptable. For a 5+ hour mission or a global power sortie, head and neck fatigue would be a problem.
- Weight and bulkiness are too much for operational crews – would have bumped side window looking at threats. Helmet – fair (test object)
- It didn't feel much heavier than a conventional helmet and it was well balanced.
- Comfortable.
- Weight is comparable to current helmet w/ NVG attached.
- The helmet hurt the back of my head and in general was too heavy.
- CG (center of gravity) was good - weight would cause fatigue.
- Prototype ok.

3.a. Rate the **Operational Utility** of HMD JDAM Launch Acceptability Region (LAR) information when on the “black line”. Use the following scale:

Ratings:	
7 Totally Acceptable	2
6 Very Acceptable	4
5 Somewhat Acceptable	3
4 Borderline	
3 Somewhat Unacceptable	1
2 Very Unacceptable	
1 Totally Unacceptable	

RATING: Average: 5.6

Comments:

- For some reason, for me the arrow and giant LAR was not as intuitive to use and interpret as the God's eye view of all the LARs superimposed with the course line.
- Good SA on where the LARs were located
- Hard to tell when the LAR is over the DMPI. Had to rely too much on the arrow.
- It provided definitive data on where the DMPIs were and where the LAR was. The inclusion of threat data was a bonus. This information will allow pilots to put the DMPIs in one side of the LAR to stay further from threats.
- Better than a LAR, except for factoring in CRL location. Concept is great.
- Concept is exactly what we need for LAR situational awareness. This particular display gives the information too low in the field of view – causes tendency to look down when pilot needs to be looking outside.
- The “big foot” was a good representation but I think could use some major improvements.
- There does not exist time to JDAM release / therefore difficult to know when to get into parameters. I do like the LAR depiction.
- Good SA – easy to understand aspect and relationship to DMPIs and LAR.

3.b. Rate the **Operational Utility** of HMD JDAM Launch Acceptability Region (LAR) information when somewhat off of the “black line”. Use the following scale:

Ratings:	
7 Totally Acceptable	2
6 Very Acceptable	4
5 Somewhat Acceptable	3
4 Borderline	
3 Somewhat Unacceptable	1
2 Very Unacceptable	
1 Totally Unacceptable	

RATING: **Average: 5.6**

Comments:

- The arrow for me is not as intuitive as the multiple DMPIs with course lines depicted.
- Good SA
- Have to rely on arrow symbology to turn jet in right direction. Having LAR depicted on ground puts your head down – looking through/below VSD
- The HMD provides a steering arrow directly to the DMPIs. This allowed me to put the LAR over the DMPIs without OSO steering. With the HMD I actually knew that the weapons would come out.
- Adds SA to current displays.

3.c. Rate the **Operational Utility** of HMD JDAM Launch Acceptability Region (LAR) information when significantly off of the “black line”. Use the following scale:

	Ratings:
7 Totally Acceptable	1
6 Very Acceptable	3
5 Somewhat Acceptable	4
4 Borderline	
3 Somewhat Unacceptable	1
2 Very Unacceptable	1
1 Totally Unacceptable	

RATING: **Average: 5.0**

Comments:

- The arrow for me is not as intuitive as the multiple DMPIs with course lines depicted.
- Nice steering cues to the LAR.
- Difficult to tell where the LAR / weapon footprints are – have to rely on arrow symbol to turn jet. Look down angle unacceptable – though/below VSD.
- The ability to simply look to the right or left and see the DMPIs was very useful. It will help pilots operationally because they can quickly see a bearing and distance relationship between the LARs and DMPIs.
- A little more difficult to fly and see the DMPIs.
- I liked the arrow to the heading bug to get back on the black line.
- When maneuvering, for threats it is important to know DMPI order (i.e. blocked weapons). A number needs to be added to diamond.
- More fusion required – distance to LAR etc. requires a more composite crosscheck.

4. Rate the **Operational Utility** of HMD Navigation information (i.e., both horizontal and vertical navigation). Use the following scale:

	Ratings:
7 Totally Acceptable	1
6 Very Acceptable	3
5 Somewhat Acceptable	4
4 Borderline	1
3 Somewhat Unacceptable	1
2 Very Unacceptable	
1 Totally Unacceptable	

RATING: **Average: 5.2**

Comments:

- Nice to have. Definitely needed, along with the LAR info. Would add “G” display and possibly AOA, as it would be very easy to over G the jet with all of the heads up time and no G display.
- Navigation info to the next steer point was good. The problem is having to look at the HMD and the VSD to navigate. Either put the necessary navigation symbols on the HMD display or go with a head down display.
- Need more navigation symbology and numbers to actually navigate.
- The airspeed and altitude information was good, but they may be easier to read if they were not in the extreme corners. Maybe they should be at eye level to the left and right, like most fighter HUDs. It would also be very useful if a velocity vector or the FPAs were displayed as they are on the VSD. This would make it easier to fly heads up.
- You always know which direction the next destination is.
- Vertical navigation would require some sort of pitch ladder from the VSD/ADI – a “control instrument”. Altimeter displayed is just a performance instrument. Suggest a limited compass rose for horizontal navigation and a pitch ladder for vertical navigation.
- I thought the mach, IAS, ALT, TTG & destination were great although I found myself going back to my instruments. Perhaps these just take some getting used to.
- Low rating is probably due to unfamiliarity of pitch bank displays. Although, once I figured out I could look through to instruments was better.

5. Rate the **Operational Utility** of HMD Threat information. Use the following scale:

	Ratings:
7 Totally Acceptable	2
6 Very Acceptable	4
5 Somewhat Acceptable	1
4 Borderline	2
3 Somewhat Unacceptable	
2 Very Unacceptable	1
1 Totally Unacceptable	

RATING: **Average: 5.3**

Comments:

- Any threat info is better than what we have now. Again however, I think I’m partial to the God’s eye view rather than the chevrons.
- Good SA on where the threats are but there is no real range info on how far away the threats are. With no range to threat info it is less useful.
- Chevrons in threat environment required a lot of head movement to tell what threats were out there. Maybe put a number by the chevron so less head movement is required.

- It was very nice to finally know where threats were without having to rely on interphone communications from the DSO. It was also helpful because it allowed me to know where threats were without memorizing locations called out by the DSO. If I forgot where the SA3 was, I could just look around and find it.
- Threat type and aspect is fine but I was not able to discern range to the threat (very important) with this display.
- You can't beat knowing exactly where the threats are in reference to your position and DMPIs.
- The screen does not have scale markings. A threat ring would be helpful to know when you are flying in the WEZ. The threats at six o'clock might be added to bottom of the screen so the pilot does not have to completely turn around cranium to know what is at six.
- Good understanding of threat location. Scale a bit ambiguous – training or final production item.

6. Rate the **Legibility** of the HMD symbology and alphanumerics (e.g., resolution, clarity, jitter, contrast, brightness, stroke width, etc.). Use the following scale:

	Ratings:
7 Totally Acceptable	
6 Very Acceptable	4
5 Somewhat Acceptable	1
4 Borderline	3
3 Somewhat Unacceptable	1
2 Very Unacceptable	1
1 Totally Unacceptable	

RATING: Average: 4.6

Comments:

- LAR / DMPI was fine but the numbers were jittery and therefore distracting.
- Jitter was distracting. The lack of visuals in the sim made it hard to judge the overall picture.
- Left eye focus was blurry + symbology jittered.
- The only problem was the airspeed and altitude information seemed to jitter.
- I found upper right (TTG & altimeter) a little difficult to read because of size – too small – required extra attention to read display.
- Could increase the clarity and sharpness of the image in general.
- Too much jitter when turning cranium – cannot read upper corners.
- Good clear presentation.

7. Rate the **Size** of the HMD symbols and alphanumerics. Use the following scale:

	Ratings:
7 Totally Acceptable	1
6 Very Acceptable	3
5 Somewhat Acceptable	4
4 Borderline	1
3 Somewhat Unacceptable	1
2 Very Unacceptable	
1 Totally Unacceptable	

RATING: **Average: 5.2**

Comments:

- Numbers were jittery so hard to evaluate. I think their size would be ok if they weren't jittery.
- The upper speed / mach / altitude and pitch/ bank symbols are too small
- Hard to tell the difference between 6 and 8 inside threat ring. Other numbers at top of displays were fuzzy.
- The navigation information and airspeed/altitude could be a little bigger to make them easier to read.
- I found upper right (TTG & altimeter) a little difficult to read because of size – too small – required extra attention to read display.
- DMPIs and threats need to be bigger. They should catch your eye and not make you work to find them.
- Good.

8. Were all the HMD **Lines** clear and distinct?

Curved lines?	YES	<u>9</u>	NO	<u>1</u>
Diagonal lines?	YES	<u>9</u>	NO	<u>1</u>
Vertical lines?	YES	<u>10</u>	NO	
Horizontal lines?	YES	<u>10</u>	NO	

Comments:

9. Rate the acceptability of the **Overall Viewability** information (e.g., display size, symbol motion, etc.) of the HMD information. Use the following scale

	Ratings:
7 Totally Acceptable	1
6 Very Acceptable	4

5 Somewhat Acceptable	3
4 Borderline	2
3 Somewhat Unacceptable	
2 Very Unacceptable	
1 Totally Unacceptable	

RATING: Average: 5.4

Comments:

- Takes getting used to and once again, not as intuitive (for me) as course lines + DMPIs from a God's eye view / straight down viewpoint.
- Upper symbols too small and the navigation info needs to be included
- HMD tracked horizon ok – no lags noted
- Great – except as noted in previous comments
- Increase threat and DMPI size.
- Glare needs to be addressed.
- Good location and viewability.

10. All things considered, rate the **Target Situational Awareness** given by the HMD in the B-1B. Use the following scale:

	Ratings:
7 Totally Acceptable	1
6 Very Acceptable	5
5 Somewhat Acceptable	3
4 Borderline	
3 Somewhat Unacceptable	
2 Very Unacceptable	1
1 Totally Unacceptable	

RATING: Average: 5.4

Comments:

- Much better than nothing, but still needs work
- Good SA on where the targets were located.
- Types of symbols need to be re-addressed! Having a ground depiction of JDAM footprint that has to be dragged over a DMPI requires too much heads down looking. Found myself looking at HIS + control stick! Maybe consider upside-down wedding cake for LAR depiction so my head would be more level at my altitude.
- It would have been perfect but it still does not provide steering information to a fixed LAR which would exist with an azimuth constrained JDAM.
- Really liked seeing the footprint of where we can send a JDAM.
- Concept works well – LAR display needs to be higher in field of view.
- Good SA

11. All things considered, rate the **OVERALL Operational Utility** of a HMD in the B-1B. Use the following scale:

Ratings:	
7 Totally Acceptable	1
6 Very Acceptable	5
5 Somewhat Acceptable	3
4 Borderline	
3 Somewhat Unacceptable	
2 Very Unacceptable	1
1 Totally Unacceptable	

RATING: Average: 5.4

Comments:

- Interesting dilemma. Adds the nav info that was missing in the 6x8 but symbology is not as intuitive. Also solves readability from left vs. right seat (i.e. N/A). Is it NVG compatible?
- Too much looking between VSD and HMD. Symbology is too small at the top and not all-inclusive (i.e. the navigation). The weight and overall cumbersome fit will be a fatigue issue.
- If properly done, a HMD would be very beneficial for both JDAM releases and threat avoidance! Consider God's eye + fly-through graphics options instead of current design. Goal is to reduce head movement – not to increase it! (Very difficult to see plus ID threats at 3+9 o'clock.)
- This is a giant leap forward in improving the SA of the pilots in the B-1B. This should allow B-1B pilots to fly with their heads up instead of trying to figure out navigation and target steering from HDDs in the cockpit.
- It's tougher to fly the airplane and look through the HMD, but it provides incredible SA on target, footprint, and threat location.
- Need to combine with an NVG image for night operations.
- I think with some improvements in the size of the device, clarity of the image and proper training that this could be a useful device.
- From a training point of view it would be more difficult to teach a guy how to use this compared to just looking at the God's eye view LCD. It was more difficult to include crosscheck than LCD.
- Good – no major problems – would require additional training time – not as intuitive as flat screen,

SECTION 2 – 4” X 4” HDD

12. Rate the acceptability of the **Physical Location** of the 4” X 4” HDD (e.g., control reachability, look angle, parallax, visual obstructions, etc.). Use the following scale:

	Ratings:
7 Totally Acceptable	8
6 Very Acceptable	1
5 Somewhat Acceptable	1
4 Borderline	
3 Somewhat Unacceptable	
2 Very Unacceptable	
1 Totally Unacceptable	

RATING: Average: 6.7

Comments:

- Very optimum. Pretty much right in the field of view and very easy to incorporate in instrument scan. Solves right and left seat issue.
- Great location. Very little movement within my crosscheck. All of the info I need is right there in my field of view.
- Had to get used to looking down and left.
- Very easy to see, and it did not alter the rest of the cockpit instrumentation to be put in.
- Very easy crosscheck between VSD and 4x4. Better than 6x8, easier to fly.
- Very easy location to glance down at and determine your position to the LARs.
- Excellent location for pilot – clearly visible.

13. Rate the **Operational Utility** of 4” X 4” HDD JDAM Launch Acceptability Region (LAR) information. Use the following scale:

	Ratings:
7 Totally Acceptable	7
6 Very Acceptable	3
5 Somewhat Acceptable	
4 Borderline	
3 Somewhat Unacceptable	
2 Very Unacceptable	
1 Totally Unacceptable	

RATING: Average: 6.7

Comments:

- No problems, very intuitive to use.
- Great SA on the LARs
- Easy to find and steer to all LARs
- The LAR depiction on the HDD was great. It was also easier to see the relation of the black line to the LARs. This would also be helpful if using a launch point or a fixed LAR with an azimuth constrained JDAM. The HDD is a better tool for ADFing back to a planned route of flight than the HMD.
- The location of the LARs to your course and current heading was easy to determine.
- Very good, easily readable – no problems.

14.a. Rate the **Operational Utility** of 4” X 4” HDD JDAM Launch Acceptability Region (LAR) information when on the “black line”. Use the following scale:

Ratings:	
7 Totally Acceptable	8
6 Very Acceptable	2
5 Somewhat Acceptable	
4 Borderline	
3 Somewhat Unacceptable	
2 Very Unacceptable	
1 Totally Unacceptable	

RATING: **Average: 6.8**

Comments:

- No problems.
- Again, quick glances to verify LAR releases.
- When on the black line the HMD is good enough by itself for LAR information, but the location of bullseye and threat information was very good.

14.b. Rate the **Operational Utility** of 4” X 4” HDD JDAM Launch Acceptability Region (LAR) information when somewhat off of the “black line”. Use the following scale:

Ratings:	
7 Totally Acceptable	8
6 Very Acceptable	1
5 Somewhat Acceptable	1
4 Borderline	
3 Somewhat Unacceptable	
2 Very Unacceptable	

1 Totally Unacceptable

RATING: **Average: 6.7**

Comments:

- Again very easy to “thread the LARs” rather than skim the edges and maybe miss one or two.
- No problems.
- Very easy to correct back to LARs – or pick which part of LAR to fly through (due to threats).
- This is where the HDD begins to be extremely useful. It provides better steering cues to get back to the black line than the HMD did.
- DMPI order.

14.c. Rate the **Operational Utility** of 4” X 4” HDD JDAM Launch Acceptability Region (LAR) information when significantly off of the “black line”. Use the following scale:

	Ratings:
7 Totally Acceptable	8
6 Very Acceptable	1
5 Somewhat Acceptable	1
4 Borderline	
3 Somewhat Unacceptable	
2 Very Unacceptable	
1 Totally Unacceptable	

RATING: **Average: 6.7**

Comments:

- Bottom line: a picture is worth 1000 words! Very pilot friendly.
- Easy to find the LARs and maneuver to them.
- Only way to get back to LAR without interphone chatter!
- The HDD is very good for providing information on where the black line is in relation to the aircraft.
- Just one additional tool to know where you need to rollout to head into all the LARs.
- Easy to understand and position aircraft into LAR basket. Very intuitive from God’s eye view.

15. Rate the **Operational Utility** of 4" X 4" HDD Navigation information (i.e., both horizontal and vertical navigation). Use the following scale:

	Ratings:
7 Totally Acceptable	4
6 Very Acceptable	4
5 Somewhat Acceptable	2
4 Borderline	
3 Somewhat Unacceptable	
2 Very Unacceptable	
1 Totally Unacceptable	

RATING: **Average: 6.2**

Comments:

- Not a problem. LARs and course lines are plainly visible.
- Vertical navigation is good. Horizontal nav is still provided by VSD but it was much easier to scan back and forth between the 4x4 and the VSD.
- Good for horizontal navigation.
- The HDD was very good for horizontal navigation, but has no vertical navigation information. It also doesn't need vertical navigation info because it is next to the VSD. It would be good if the steer point numbers were displayed, and it would be very, very nice to have a moving map and digital bulls eye always displayed to the aircraft's position.
- Vertical navigation information not incorporated on HDD, but easily integrated from flight instruments.
- Did not give any vertical navigation. Still needed to crosscheck altimeter.
- Initially the 4x4 provided easier instrument crosscheck than the 6x8 due to its proximity to the instruments.
- Very good.

16. Rate the **Operational Utility** of 4" X 4" HDD Threat information. Use the following scale:

	Ratings:
7 Totally Acceptable	4
6 Very Acceptable	5
5 Somewhat Acceptable	1
4 Borderline	
3 Somewhat Unacceptable	
2 Very Unacceptable	
1 Totally Unacceptable	

RATING: Average: 6.3

Comments:

- Very intuitive. Only thing I would add would be a threat ring along with numbers but certainly not at the expense of the LAR depictions.
- It provided both azimuth and range info – outstanding.
- Would like to see scaled threat rings (corrected for current altitude).
- It was better at providing threat range and jamming status than the HMD, but the HMD provides a better quick reference for threat locations and allows pilots to look for a launch. The HMD is quicker, but the HDD provides more accurate and more information.
- It is great to know when your jamming a threat and where the threat is in reference to your flight path.
- Size of threat rings.
- Good SA – range, aspect. All easy to see and understand.

17. Rate the **Legibility** of the 4” X 4” HDD symbology and alphanumerics (e.g., resolution, clarity, jitter, contrast, brightness, stroke width, etc.). Use the following scale:

	Ratings:
7 Totally Acceptable	5
6 Very Acceptable	3
5 Somewhat Acceptable	2
4 Borderline	
3 Somewhat Unacceptable	
2 Very Unacceptable	
1 Totally Unacceptable	

RATING: Average: 6.3

Comments:

- No problems.
- Sharp image. Make sure the compass rose is in magnetic heading. It appeared to be in true heading which is useless to a pilot.
- Great, no problems.
- Surprisingly good. The fidelity is excellent for such a small instrument.
- Easy to read – bright – good contrast.

18. Rate the **Size** of the 4" X 4" HDD symbols and alphanumerics. Use the following scale:

	Ratings:
7 Totally Acceptable	5
6 Very Acceptable	4
5 Somewhat Acceptable	1
4 Borderline	
3 Somewhat Unacceptable	
2 Very Unacceptable	
1 Totally Unacceptable	

RATING: **Average: 6.4**

Comments:

- No problems
- 4x4 size was very usable, no problems with the view or size.
- Very nice.
- No trouble reading anything.
- Easy to read all numbers and LARs
- Easy to read symbols on screen.

19. Were all the 4" X 4" HDD **Lines** clear and distinct?

Curved lines?	YES	<u>8</u>	NO	<u>2</u>
Diagonal lines?	YES	<u>10</u>	NO	<u> </u>
Vertical lines?	YES	<u>10</u>	NO	<u> </u>
Horizontal lines?	YES	<u>10</u>	NO	<u> </u>

Comments:

- Some distortion on curved lines (resolution?).

20. Rate the acceptability of the **Overall Viewability** of the 4" X 4" HDD information (e.g., display size, symbol motion, etc.). Use the following scale

	Ratings:
7 Totally Acceptable	5
6 Very Acceptable	3
5 Somewhat Acceptable	2
4 Borderline	
3 Somewhat Unacceptable	
2 Very Unacceptable	
1 Totally Unacceptable	

RATING: **Average: 6.3**

Comments:

- It provides the needed info in an easy to scan location.
- Not as good as 6x8.
- Good viewability.

21. All things considered, rate the **Target Situational Awareness** given by the 4" X 4" HDD in the B-1B. Use the following scale:

Ratings:	
7 Totally Acceptable	6
6 Very Acceptable	3
5 Somewhat Acceptable	1
4 Borderline	
3 Somewhat Unacceptable	
2 Very Unacceptable	
1 Totally Unacceptable	

RATING: **Average: 6.5**

Comments:

- Good SA on target location.
- This, combined with the HMD solves the problem of threat location, LAR location, and navigational information. The HDD will allow a pilot to quickly steer to the black line which is essential when using a launch point or an azimuth constrained LAR.
- I wish we had something like that now! I feel confident I could maneuver in any direction and still release weapons.
- No problem integrating into crosscheck and processing.

22. All things considered, rate the **OVERALL Operational Utility** of a 4" X 4" HDD in the B-1B. Use the following scale:

Ratings:	
7 Totally Acceptable	7
6 Very Acceptable	3
5 Somewhat Acceptable	
4 Borderline	
3 Somewhat Unacceptable	

2 Very Unacceptable
1 Totally Unacceptable

RATING: Average: 6.7

Comments:

- Easy to scan between VSD and 4x4 and the info provided is what is useful and needed by the pilot.
- A lot better than Block D only. (Need bay door indications on SMS panel.) God's eye view of LARs make released simple – even with threats.
- The only things that would make it better would be a choice of ranges, a moving map, and bulls eye to the aircraft location. It would be great to have this in the airplane because the pilots would have a much easier time returning to the black line. It also provides threat info, nav info, and target info in one place. The HDD would be a great tool for the pilot not flying while the pilot flying concentrated on clearing outside with the HMD.
- Like the location of the 4x4 more than the 6x8.
- Lets get this program going and get these onboard!!
- Similar to the 8x6 in excellent operational utility. Probably better initially because the cockpit layout (i.e. old cockpit displays) doesn't change.
- Very good.

SECTION 3 – 8” x 6” HDD

23. Rate the acceptability of the **Physical Location** of the 8” x 6” HDD (e.g., control reachability, look angle, parallax, visual obstructions, etc.). Use the following scale:

	Ratings:
7 Totally Acceptable	3
6 Very Acceptable	5
5 Somewhat Acceptable	2
4 Borderline	
3 Somewhat Unacceptable	
2 Very Unacceptable	
1 Totally Unacceptable	

RATING: Average: 6.1

Comments:

- No problems from the left seat, however, question arises as to what it would be like from the right seat. Display is nice and large, seems easy to read.
- I was in the left seat. The 6x8 display is position more favorable towards the left seat. I don't think the right seat would have a problem.
- (Rating 6) From the left seat – might be harder to see from the right seat.
- It should be a good location from both pilots' seats.
- Understand fit problems, but this display would be best placed closer to primary flight instruments.

24.a. Rate the **Operational Utility** of 8” x 6” HDD JDAM Launch Acceptability Region (LAR) information when on the “black line”. Use the following scale:

	Ratings:
7 Totally Acceptable	7
6 Very Acceptable	3
5 Somewhat Acceptable	
4 Borderline	
3 Somewhat Unacceptable	
2 Very Unacceptable	
1 Totally Unacceptable	

RATING: Average: 6.7

Comments:

- Any LAR visual depictions are much greater than what we now have (i.e. nothing).
- There needs to be some way of telling what LAR is tied to what weapon.

- Easy cross check LAR location – don't have to constantly worry about where the LARs are.
- When on the black line the HMD is good enough by itself for LAR information, but the location of bullseye and threat information was very good.
- It gives great situational awareness to the LARs so that the aircraft can be maneuvered so that its flight path will pass through all of them.
- Very good SA on where LARs are and aircraft orientation to them. Easy to understand relationship.

24.b. Rate the **Operational Utility** of 8" x 6" HDD JDAM Launch Acceptability Region (LAR) information when somewhat off of the "black line". Use the following scale:

	Ratings:
7 Totally Acceptable	7
6 Very Acceptable	2
5 Somewhat Acceptable	1
4 Borderline	
3 Somewhat Unacceptable	
2 Very Unacceptable	
1 Totally Unacceptable	

RATING: **Average: 6.6**

Comments:

- Very easy to make small, last minute corrections (i.e. thread the center of the LARs vs. hoping the OSO has you hit the edges and maybe even miss one or two).
- No problems.
- LARs allowed me to correct my flight path so I could intersect all bi-ellipses.
- This is where the HDD begins to be extremely useful. It provides better steering cues to get back to the black line than the HMD did.
- It gives great situational awareness to the LARs so that the aircraft can be maneuvered so that its flight path will pass through all of them.
- Conceptionally – good information and display. Easy to understand maneuvering requirements to put aircraft into LAR.

24.c. Rate the **Operational Utility** of 8" x 6" HDD JDAM Launch Acceptability Region (LAR) information when significantly off of the "black line". Use the following scale:

	Ratings:
7 Totally Acceptable	7
6 Very Acceptable	2
5 Somewhat Acceptable	1
4 Borderline	

- 3 Somewhat Unacceptable
- 2 Very Unacceptable
- 1 Totally Unacceptable

RATING: Average: 6.6

Comments:

- Again, outstanding. SA is 100X greater. Very pilot friendly.
- Easy to maneuver the A/C to the LAR. I maintained high situational awareness on where the LARs were located.
- Extremely easy to steer jet back to LARs – no interphone required!
- The HDD is very good for providing information on where the black line is in relation to the aircraft.
- Huge SA with this display.
- I found no difference, easy in all cases.
- DMPI order needs to be added / time to release.
- Easy to understand maneuvering requirements to put aircraft into LAR.

25. Rate the **Operational Utility** of 8” x 6” HDD Navigation information (i.e., both horizontal and vertical navigation). Use the following scale:

- | | |
|-------------------------|----------|
| | Ratings: |
| 7 Totally Acceptable | 2 |
| 6 Very Acceptable | 5 |
| 5 Somewhat Acceptable | 3 |
| 4 Borderline | |
| 3 Somewhat Unacceptable | |
| 2 Very Unacceptable | |
| 1 Totally Unacceptable | |

RATING: Average: 5.9

Comments:

- Would be nice to have small HUD type of #'s in upper corners for airspeed, AOA, & altitude, I would suspect that that would help the right seat pilot tremendously also.
- I found myself looking between the VSD and the 6x8 HDD to fine-tune my navigation. If there was some sort of steering cue on the HDD I wouldn't have to look at the VSD for navigation.
- Easy to see course and destinations – would like more weapons info.
- The HDD was very good for horizontal navigation, but has no vertical navigation information. It also doesn't need vertical navigation info because it is next to the VSD. It would be good if the steer point numbers were displayed, and it would be very, very nice to have a moving map and digital bulls eye always displayed to the aircraft's position.

- Vertical navigation information not present on HDD, but easily incorporated from flight instruments.
- No vertical navigation available.
- Good overall SA. Small bits of info missing – does not impact utility, CNMS info would be helpful.

26. Rate the **Operational Utility** of 8” x 6” HDD Threat information. Use the following scale:

Ratings:

7 Totally Acceptable	3
6 Very Acceptable	7
5 Somewhat Acceptable	
4 Borderline	
3 Somewhat Unacceptable	
2 Very Unacceptable	
1 Totally Unacceptable	

RATING: **Average: 6.3**

Comments:

- Again, whatever threat info we can see up front is an exponential improvement to current threat info (i.e. the DSO’s voice).
- Excellent SA on threats.
- Adding threat rings (corrected for altitude) would be a great improvement! (Stay out of threat rings – but go through LAR rings.)
- It was better at providing threat range and jamming status than the HMD, but the HMD provides a better quick reference for threat locations and allows pilots to look for a launch. The HMD is quicker, but the HDD provides more accurate and more information.
- I especially like the idea of knowing where threats are in relation to the jet and the target.
- Threat rings increase SA.
- Good presentation. Very traditional format.

27. Rate the **Legibility** of the 8” x 6” HDD symbology and alphanumerics (e.g., resolution, clarity, jitter, contrast, brightness, stroke width, etc.). Use the following scale:

Ratings:

7 Totally Acceptable	6
6 Very Acceptable	4

- 5 Somewhat Acceptable
- 4 Borderline
- 3 Somewhat Unacceptable
- 2 Very Unacceptable
- 1 Totally Unacceptable

RATING: Average: 6.6

Comments:

- Screen was very user friendly.
- No problems from left seat.
- Great.
- Looked good to me.
- Easy to read although the picture could be sharper. It looked better on the 4x4.
- Easy to read.

28. Rate the **Size** of the 8" x 6" HDD symbols and alphanumerics. Use the following scale:

Ratings:

- | | |
|-------------------------|---|
| 7 Totally Acceptable | 7 |
| 6 Very Acceptable | 3 |
| 5 Somewhat Acceptable | |
| 4 Borderline | |
| 3 Somewhat Unacceptable | |
| 2 Very Unacceptable | |
| 1 Totally Unacceptable | |

RATING: Average: 6.7

Comments:

- This study was conducted in daylight conditions. Might want to look with a dark cockpit and a look with a dark cockpit with a pair of NVGs on.
- Could be smaller and still be readable from the left seat.
- It was much easier to see the information on the 6x8 display. In a dark cockpit, bouncing along in a low level, bigger numbers are much easier to see and interpret.
- Would like to see when doors are opening and bombs are away, CRL rotating – so I can turn the jet in between releases.
- Easy to read – bright.

29. Were all the 8" x 6" HDD **Lines** clear and distinct?

Curved lines?	YES	<u>9</u>	NO	<u>1</u>
Diagonal lines?	YES	<u>10</u>	NO	<u> </u>
Vertical lines?	YES	<u>10</u>	NO	<u> </u>
Horizontal lines?	YES	<u>10</u>	NO	<u> </u>

Comments:

- Very readable.
- No problems.
- Turn radius depictions would be helpful
- Good clarity.

30. Rate the acceptability of the **Overall Viewability** of the 8" x 6" HDD information (e.g., display size, symbol motion, etc.). Use the following scale

	Ratings:
7 Totally Acceptable	6
6 Very Acceptable	2
5 Somewhat Acceptable	2
4 Borderline	
3 Somewhat Unacceptable	
2 Very Unacceptable	
1 Totally Unacceptable	

RATING: Average: 6.4

Comments:

- Very readable.
- This study was conducted in daylight conditions. Might want to look with a dark cockpit and a look with a dark cockpit with a pair of NVGs on.
- I think the 4x4 does the same job, if not better, and takes up less space. Two 4x4s would be more beneficial and no information would be lost.
- Very good.

31. All things considered, rate the **Target Situational Awareness** given by the 8" x 6" HDD the B-1B. Use the following scale:

Ratings:

7 Totally Acceptable	7
6 Very Acceptable	3
5 Somewhat Acceptable	
4 Borderline	
3 Somewhat Unacceptable	
2 Very Unacceptable	
1 Totally Unacceptable	

RATING: Average: 6.7

Comments:

- Other than not knowing which weapon was tied to which LAR. The SA of where the targets were located was great.
- God's eye view of dynamic LARs made releases very easy – especially when off black line.
- This, combined with the HMD solves the problem of threat location, LAR location, and navigational information. The HDD will allow a pilot to quickly steer to the black line, which is essential, when using a launch point or an azimuth constrained LAR.
- SA regarding LAR location is excellent, although there is no actual target information.

32. All things considered, rate the **OVERALL Operational Utility** of a 8" x 6" HDD in the B-1B. Use the following scale:

	Ratings:
7 Totally Acceptable	5
6 Very Acceptable	4
5 Somewhat Acceptable	1
4 Borderline	
3 Somewhat Unacceptable	
2 Very Unacceptable	
1 Totally Unacceptable	

RATING: Average: 6.4

Comments:

- Fantastic SA. Drastic improvement. Only possible problems I see is the flyability from the right seat, NVG compatible?, and also if the screen dies, where how do we display aircraft configuration. Suggestion: remove the "boat anchor" external fuel panel and put the mechanical configuration display in its place as a back up. All small things though for the availability of visual LAR info.
- The size and easy use was a great benefit on SA. Vastly improved over current B-1 setup.
- Need to see from right seat.

- The only things that would make it better would be a choice of ranges, a moving map, and bulls eye to the aircraft location. It would be great to have this in the airplane because the pilots would have a much easier time returning to the black line. It also provides threat info, nav info, and target info in one place. The HDD would be a great tool for the pilot not flying while the pilot flying concentrated on clearing outside with the HMD. I liked the bigger display because it was easier to see the bigger numbers, but other pilots may want their own display so they can set their own preferences. My preference is the bigger display.
- Only concern was cockpit placement.
- I think we could put up something more useful in the space the 8x6 takes up. Two 4x4s is my suggestion.
- The overall tactical/operational utility is excellent. I thought the general A/C information (i.e. flaps, wing trim, etc.) was difficult to read though and seemed to clutter the display.
- Very good presentation. Limited training required. Clear, easy to understand and use.

SECTION 4 – Block D Displays

33. Rate the acceptability of the **Physical Location** of the Block D Displays (e.g., control reachability, look angle, parallax, visual obstructions, etc.). Use the following scale:

	Ratings:
7 Totally Acceptable	1
6 Very Acceptable	5
5 Somewhat Acceptable	
4 Borderline	1
3 Somewhat Unacceptable	1
2 Very Unacceptable	2
1 Totally Unacceptable	

RATING: Average: 4.8

Comments:

- The CNMS panel is partially obscured by the flap/slat handle from the copilots seat.
- CNMS is most useful Block D display. Location is not optimum due to “heads down” required for pilot.
- Normal Block D information is very lacking. Very limited SA – not much information.

34.a. Rate the **Operational Utility** of Block D Displays JDAM Launch Acceptability Region (LAR) information when on the “black line”. Use the following scale:

	Ratings:
7 Totally Acceptable	
6 Very Acceptable	1
5 Somewhat Acceptable	2
4 Borderline	1
3 Somewhat Unacceptable	3
2 Very Unacceptable	2
1 Totally Unacceptable	1

RATING: Average: 3.4

Comments:

- When on the black line there is not a real problem. Fly to the point and launch.
- Had no indications of LARs! No idea when bays/doors selected. Would have needed WSO interphone to confirm doors and release.

- With only the standard Block D displays I have no idea where the LARs actually are. I need to rely totally on the OSO to provide steering information.
- If on the black line, LAR will occur at a pre-planned point. The display shows countdown to LAR but there is no particular LAR display. Black line and mission planned parameters are essential to display guaranteeing weapon release.
- If you stay on black line, you have ok information – enough to get weapons out – not much more.

34.b. Rate the **Operational Utility** of Block D Displays JDAM Launch Acceptability Region (LAR) information when somewhat off of the “black line”. Use the following scale:

Ratings:

7 Totally Acceptable	
6 Very Acceptable	
5 Somewhat Acceptable	
4 Borderline	3
3 Somewhat Unacceptable	1
2 Very Unacceptable	4
1 Totally Unacceptable	2

RATING: **Average: 2.5**

Comments:

- Had no indications of LARs! No idea when bays/doors selected. Would have needed WSO interphone to confirm doors and release.
- Again, as a pilot the only Block D steering information I have is the HSI. I can put the DMPIs in CNMS and fly directly at them and guarantee I will fly through LAR, but if I have an azimuth constrained weapon I may not fly through its LAR.
- Because there is no LAR depiction, it is impossible for the pilot to predict LAR entry whenever the aircraft is outside pre-planned parameters.
- You’re not sure what part of the LAR you are approaching or whether you will enter all the LARs.
- Very limited information – not useful – hard to keep SA and maneuver the aircraft into launch parameters.

34.c. Rate the **Operational Utility** of Block D Displays JDAM Launch Acceptability Region (LAR) information when significantly off of the “black line”. Use the following scale:

Ratings:

7 Totally Acceptable
6 Very Acceptable

5 Somewhat Acceptable	
4 Borderline	1
3 Somewhat Unacceptable	2
2 Very Unacceptable	1
1 Totally Unacceptable	6

RATING: Average: 1.8

Comments:

- This scenario is what we are currently faced with anytime we do any kind of threat reactions. If all is going as planned (black line) you will probably get all weapons off the jet. However, if you move the jet at all, all you currently have is a point to a DMPI centroid, maybe you'll hit all the LARs but you'll probably miss one maybe more. This is unacceptable because it forces re-attack issues, fuel, package support issues, etc. Bottom line: give us a display, we'll thread the LARs, all weapons off, all targets destroyed, and we go home.
- I have no situational awareness and LARs. The OSO needs to be totally involved for a launch.
- No idea where LARs were! (would have put DMPIs in CNMS if working) Would have required WSO chatter to steer to LARs! No idea when JDAMs were released!
- The only way to guarantee LAR entry is to fly directly at the DMPI using CNMS steering. This would negate some of the JDAMs standoff capability and would not guarantee the release of an azimuth-constrained weapon.
- The LAR info we have comes from selecting CNMS with a DMPI coordinate selected as a fly to point to give us SA on DMPI location. Requires good crew coordination to get the jet pointed back to the LAR following threat reaction etc. We also give up Bull info when doing this. Not human factors friendly when we are trying to defend the jet as well as hit the target and have to rely on OSO comm vs. DSO threat reactions to get there.
- Because there is no LAR depiction, it is impossible for the pilot to predict LAR entry whenever the aircraft is outside pre-planned parameters.
- Your not sure what part of the LAR you are approaching or whether you will enter all the LARs.
- The best you can do is to get back to black line or point nose at DMPI centroid.

35. Rate the **Operational Utility** of Block D Displays Navigation information (i.e., both horizontal and vertical navigation). Use the following scale:

	Ratings:
7 Totally Acceptable	
6 Very Acceptable	5
5 Somewhat Acceptable	3
4 Borderline	1
3 Somewhat Unacceptable	
2 Very Unacceptable	1
1 Totally Unacceptable	

RATING: **Average: 5.1**

Comments:

- Currently, our squadron has one guy in nav steering and the copilot in CNMS with either LAR entry or DMPI centroid depicted. Who is flying, who is pointed to what, what is the OSO seeing, etc., a CRM nightmare.
- Would have used CNMS.
- Block D provides a greatly increased navigational SA for the front cockpit. The ability to enter specific LAT/LONG coordinates or a radial/DME fix and fly directly to it should allow the pilots to perform some more of their own navigation.
- No problems with knowing my position with the sequenced point.
- Limited insight in maneuvering and what impact it will have on overall weapons delivery outcome – limited SA.

36. Rate the **Operational Utility** of Block D Displays Threat information. Use the following scale:

	Ratings:
7 Totally Acceptable	
6 Very Acceptable	
5 Somewhat Acceptable	1
4 Borderline	
3 Somewhat Unacceptable	
2 Very Unacceptable	1
1 Totally Unacceptable	8

RATING: **Average: 1.5**

Comments:

- Pictures are worth millions of words in this case. Currently, we're fighting, threat reacting, LARs are moving, and the DSO is trying to protect us by verbally relaying threat info. Unsat.

- I have no threat info in the front cockpit in Block D. The DSO is the only one of the crewmembers with the threat picture.
- What threats? Could not see a single one! Would have had to rely on DSO interphone or ICS warning tones.
- Block D threat information is no better than block C, at least for pilots. We will rely completely on the DSO for all threat location and status calls. Pilots need a threat display at their stations.
- There is no threat info.
- No display – threat information must be provided by DSO.
- Did not give any threat info up front.
- Threat display does not exist.
- No information displayed – only tones and DSO inputs.

37. Rate the **Legibility** of the Block D VSD symbology and alphanumerics (e.g., resolution, clarity, jitter, contrast, brightness, stroke width, etc.). Use the following scale:

	Ratings:
7 Totally Acceptable	2
6 Very Acceptable	4
5 Somewhat Acceptable	1
4 Borderline	1
3 Somewhat Unacceptable	1
2 Very Unacceptable	1
1 Totally Unacceptable	

RATING: **Average: 5.2**

Comments:

- What little symbology we have works fine. VSDs are getting old however.
- OK for ERS.
- VSD displays are very legible, I have no problem reading them.
- No problem.
- Legibility is fine in a “fresh” VSD, but as the system is aging the brightness, contrast and overall legibility are suffering.
- Adequate display – somewhat fuzzy displays.

38. Rate the **Size** of the Block D VSD symbols and alphanumerics. Use the following scale:

	Ratings:
7 Totally Acceptable	2
6 Very Acceptable	4
5 Somewhat Acceptable	1
4 Borderline	1
3 Somewhat Unacceptable	1
2 Very Unacceptable	1
1 Totally Unacceptable	

RATING: **Average: 5.2**

Comments:

- The size is fine.
- Fuzzy.

39. Were all the Block D VSD **Lines** clear and distinct?

Curved lines?	YES	<u>9</u>	NO	<u>1</u>
Diagonal lines?	YES	<u>9</u>	NO	<u>1</u>
Vertical lines?	YES	<u>9</u>	NO	<u>1</u>
Horizontal lines?	YES	<u>9</u>	NO	<u>1</u>

Comments:

- The VSDs work great.
- All fuzzy.

40. Rate the acceptability of the **Overall Viewability** of the Block D Displays information (e.g., display size, symbol motion, etc.). Use the following scale

	Ratings:
7 Totally Acceptable	1
6 Very Acceptable	5
5 Somewhat Acceptable	1
4 Borderline	1
3 Somewhat Unacceptable	
2 Very Unacceptable	2
1 Totally Unacceptable	

RATING: **Average: 5.0**

Comments:

- The VSD is fine but it doesn't give you the information you need.

- The only problem with viewing Block D displays is that the CNMS panel is partially hidden by the flap/slat handle from the copilots seat.

41. All things considered, rate the **Target Situational Awareness** given by the Block D Displays in the B-1B. Use the following scale:

	Ratings:
7 Totally Acceptable	
6 Very Acceptable	1
5 Somewhat Acceptable	1
4 Borderline	1
3 Somewhat Unacceptable	1
2 Very Unacceptable	3
1 Totally Unacceptable	3

RATING: **Average: 2.7**

Comments:

- The current system works but is a CRM nightmare. We need LAR depiction and threat depiction up front and we need it yesterday.
- Unless you are on the black line you are lost. There is no SA on where or how the LAR is changing.
- Have no visual indications of where LARS or threats are!
- The only great improvement over Block C is the ability to have steering to the DMPI displayed on the CNMS panel. The pilots have very little information on where LARs are or on how to steer to them.
- We must plan for “off the black line” flying as it is most likely in combat employment.
- Pilots only receive steering info and time to the first LAR. The pilot does not know if current heading will fly through all LARs. This is unacceptable in a multi DMPI target area.

42. All things considered, rate the **OVERALL Operational Utility** of Block D Displays in the B-1B. Use the following scale:

	Ratings:
7 Totally Acceptable	
6 Very Acceptable	1
5 Somewhat Acceptable	2
4 Borderline	1
3 Somewhat Unacceptable	1

2 Very Unacceptable	4
1 Totally Unacceptable	1

RATING: Average: 3.2

Comments:

- The current system works but is a CRM nightmare. We need LAR depiction and threat depiction up front and we need it yesterday.
- No threat or LAR SA. Unacceptable!
- Pilots have to rely on OSO/DSO interphone calls or CNMS for threat avoidance & JDAM release.
- The CNMS greatly increases navigational SA in the pilot's station, and it also reduces the effort required for things such as have quick and KY 58 operation. It doesn't greatly increase SA on LARs or target steering or threat information.
- Navigation displays = acceptable
LAR information = unacceptable
Threats = marginal, but obviously can be trained as a crew.
- For many reasons Block D displays are poor. When off the black line there is no SA on LAR location especially for multiple DMPIs. No threat information. Might as well be flying Cessna 172.
- The overall rating is based on current info displayed – crewmembers have techniques using CNMS to increase target SA. The current displays are acceptable in a benign threat environment.
- Very limited SA! Only know what was planned and your current location – lots of fusion required to build mental picture of mission.

BIBLIOGRAPHY

B-1B Human Factors Baseline Study Report, ASC-TR-1999-5007, Kalman, Kline, Provost, Gable, & Taylor, November, 1999

Report on Two Sizes of B-1B Liquid Crystal Displays (LCDs) for Displaying Threat and other Functions at the Pilot's Station, ASC-TR-2000-5008, Kalman, Provost, Taylor, Anesgart, and Gable, August, 2000

Report on the B-1B Alternative Launch Acceptability Region (LAR) Study, ASC-TR-2000-TBD, Provost, Kalman, Taylor, Gable, and Anesgart, April, 2000

Questionnaire Construction Manual, Research Product 89-20, Fort Hood Field Unit Systems Research Laboratory, U.S. Army Research Institute for the Behavioral and Social Sciences, June, 1989. (see also Annex in Research Product 89-21.)